EXHIBIT F

TERRATEK, INC.

Drilling and Completions Laboratory **October 1997**

ROCK LIST

TerraTek, Inc.
400 Wakara Way
Salt Lake City, UT 84108
Phone: (801)584-2441 / Fax: (801)584-2406 / E-Mail: ablack@terratek.com

Rock Type	Description	Bulk Density g/cc	Grain Density g/cc	Porosity %	Permeability darcy	Unconfined Strength psi	Confined Strength psi P_c	Young's Modulus psi	Poissons Ratio	Internal Friction °
MANCO SHALE Central Utah Core	Cretaceous, gray to black, shaly siltstone, 15-20% clay. Preserved to prevent dehydration and air slacking	2.54	2.68	7.8	$<10^{4}$	9,800	21,000 @ 4,000	2.1×10^{6}	0.36	28
WELLINGTON SHALE Central Utah Core	Cretaceous, gray to black shaly siltstone, 20-30% clay. Preserved to prevent dehydration and air slacking	2.40	2.49	8.1	$<10^{8}$	3,800				
PIERRE SHALE 1 Eastern Colorado Core	Upper Cretaceous, black claystone, very fine grained, 20-30% clay. Preserved to prevent dehydration and air slacking	2.34	2.70	16.8	10^{9}	2,200	2,500 @ 700	0.13×10^{6}	0.38	
PIERRE SHALE 2 South Dakota Core	Upper cretaceous, dark gray stone, very fine grained, 50-60% clay. Preserved to prevent dehydration and air slacking	2.00	2.60	33.0	$<10^{9}$	500				

Rock Type	Description	Bulk Density g/cc	Grain Density g/cc	Porosity %	Perme-ability darcy	Unconfined Strength psi	Confined Strength psi P_c	Young's Modulus psi	Poissons Ratio	Internal Friction ϕ
CRAB ORCHARD SANDSTONE Tennessee Quarry	Light tan, very fine grained, compact quartzose sandstone with tightly interlocking texture	2.42	2.64	6.6	0.1×10^{-3}	23,000				46
NUGGET SANDSTONE Northern Utah Quarry	Jurassic, fine-grained, nonporous, quartzose with silica cement		2.65	9.7	1×10^{-3}	18,500	42,000 @ 3,000			
TORREY BUFF SANDSTONE Central Utah Quarry	Very fine-grained, lithic arkose, subangular mono-crystalline quartz with dolomite	2.31	2.68	16.0	0.4×10^{-3}	11,100	26,000 @ 5,000	2.6×10^{6}	0.20	29
RED SANDSTONE Central Utah Quarry	Red, very fine-grained and thinly bedded sandstone			14.5	0.9×10^{-3}	10,400				
BEREA SANDSTONE Ohio Quarry	Light gray, fine grained, massive, porous sandstone, cemented to partially interlocking texture of sub-angular to round quartz grains	2.23	2.66	20.3	0.25	8,600	28,000 @ 3,000	1.9×10^{6}	0.36	
COLTON SANDSTONE Central Utah Quarry	Green River Eocene, Graywacke, typical of deep reservoir rocks, gray colored, bedded	2.32	2.65	10.9	0.34×10^{-3}	7,600	30,000 @ 10,000	2.8×10^{6}		

Rock Type	Description	Bulk Density g/cc	Grain Density g/cc	Porosity %	Perme-ability darcy	Unconfined Strength psi	Confined Strength @ P_c psi	Young's Modulus psi	Poissons Ratio	Internal Friction φ
WYOMING TAN SANDSTONE Western Wyoming Quarry	Tan sandstone		2.65	16.5	0.105					
BENTHEIMER SANDSTONE West Germany Quarry			2.64	24.0	2.0					
CASTLEGATE SANDSTONE Western Colorado Core/Quarry	Weak porous, friable sandstone	1.97	2.63	28.8	0.56	2,100	14,000 @ 3,000	0.25×10^{6}	0.40	
SALTWASH NORTH SANDSTONE Central Utah Core/Quarry	Gray, porous, friable, weak sandstone			22.3	0.5	1,800				
SALTWASH SOUTH SANDSTONE Southern Utah Core	Yellow, very porous, very friable, very weak sandstone			31.4	1.5	230				

Rock Type	Description	Bulk Density g/cc	Grain Density g/cc	Porosity %	Perme-ability darcy	Unconfined Strength psi	Confined Strength @ P_c psi	Unconfined Young's Modulus psi	Poissons Ratio	Angle of Internal Friction φ
BONNE TERRE DOLOMITE Missouri Boulder	Yellowish buff, extra fine-grained, compact dolomite. Narrow to very fine calcite-filled fractures, vugular, fractured	2.68	2.80	8.5	$0.05x10^{-6}$	25,200	48,000 @ 10,000	$8x10^{6}$	0.25	29
CARTHAGE MARBLE OR BURLINGTON LIMESTONE Missouri Quarry	Light uniform gray, fine-grained copact limestone containing numerous fossil shell fragments, cemented, crystalline texture	2.66	2.69	1.4	$2x10^{-4}$	16,000	27,000 @ 5,000	$6.8x10^{6}$	0.32	30
LUEDERS LIMESTONE Texas Quarry	Permian fine-grained, grayish tan, microscopically homogeneous and isotropic limestone	2.19	2.70	16.9	$0.8x10^{-3}$	7,000	18,000 @ 5,000	$2.4x10^{6}$	0.20	29
INDIANA OR BEDFORD LIMESTONE Indiana Quarry	Very light grayish buff, slightly porous, oolithic, bioclastic limestone	2.21	2.70	19.0	0.028	6,000		$4x10^{6}$		
AUSTIN CHALK Texas Quarry	Porous, weak limestone	1.96	2.76	28.5	$2.5x10^{-3}$	2,000	8,000 @ 4,000			

Rock Type	Description	Bulk Density g/cc	Grain Density g/cc	Porosity %	Perme-ability darcy	Unconfined Strength psi	Confined Strength psi	P_c	Unconfined Young's Modulus psi	Poissons Ratio	Angle of Internal Friction ϕ
CHARCOAL BLACK GRANITE Minnesota Quarry	Fine-grained granodiorite with abundant dark gray hornblende and biotite-rich inclusions, uniform texture and fairly isotropic	2.84		2.2	negligible	33,000			$9.7x10^6$		
SIERRA WHITE GRANITE California Quarry	White and light gray massive medium-grained granodiorite, composed of interlocking plagioclase, quartz, and mica	2.65		<1	negligible	28,000			$6x10^6$		
BERRE GRANITE Vermont Quarry	Uniform gray, black and white, medium-grained, fresh, dense granite	2.64		0.5	negligible	28,000			$6.3x10^6$		
TEXAS PINK GRANITE Texas Quarry	Light to medium pink, coarse-grained massive granite with large phenocrysts of potassium feldspar	2.64		1	negligible	23,600			$6.5x10^6$		

MISCELLANEOUS

ROCK PROPERTIES

Rock Type	Description	Bulk Density g/cc	Grain Density g/cc	Porosity %	Perme-ability darcy	Unconfined Strength psi	Confined Strength @ P_c psi	Unconfined Young's Modulus psi	Poissons Ratio	Angle of Internal Friction °
DWORSHAK GNEISS Idaho Boulder	Black and white, fine-to medium-grained granodiorite gneiss, foliated, interlocking, crystalline texture	2.79		0.24		23,500		4x10^6		
JOHN DAY BASALT (EAST) Washington Boulder	Very dark gray to black, massive compact, interlocking crystalline texture	2.76				23,400		5x10^6		
JOHN DAY BASALT (WEST) Washington Boulder	Very dark-gray to black, massive compact, interlocking crystalline texture	2.85	2.87	0.9		63,500	63,500 @ 5000	10x10^6	0.24	41
UPPER PROVO CANYON TUFF Northern Utah Boulder	Light grayish-pink homogeneous, partially welded tuff with volcanic rock fragments and glass shards, very homogeneous	2.12	2.76	24.0		4,700		1x10^6		
UNNAMED QUARTZITE Central Utah	Light-buff to white, extremely fine grained					64,000	108,500 @ 4000			

TerraTek

TerraTek Inc.

February 12, 1997

Dr. Sujian Huang
Smith Tool
P.O. Box 60068
Houston, Texas 77205 e-mail sjhuang@smith-intl.com

SUBJECT: **Single Insert Testing** *Using the Smith Tool Single Insert Test System*

TESTING BUDGET

	Cost Per Rock Sample Test	
Non-Standard ("First time") Tests		
One test per day with at least 3 Data Points per Test expected*--Labor	840	
Rock Sample Preparation in Metal Jacket with End Cap**	250	
Test Maintenance and Expendables	150	
		$1240
Repeat Type Tests		
Two Tests per day with at least 3 Data Points per Test expected*--Labor	500	
Rock Sample Preparation in Metal Jacket with End Cap**	250	
Test Maintenance and Expendables	75	
		$825

OPTIONS:

Ten End Caps and Jacket Metal or Tubes	$2200

Silicon Mold and Digital Camera Images (presented on CD-ROM) of Sample after Insert tests	$125
Standard Mud Properties measurement on test mud	$75
Basic Characterization of rock (including unconfined compressive strength, triaxial strength, density, porosity, and description)	$1200
Standard Spirt Loss on Rock for given drilling mud (uses 1-inch diameter by 3.5-inch long sample)	$2500

* Drilling Mud is not included; disposal is included.
** For lots of 10 or more samples using reusable end caps; end caps and rock are not included.

---Minimum <u>first</u> Test Program is a 20 Non-Standard Tests program---

TESTING DEFINITIONS

The **Non-Standard Tests** ("First time" tests) would be aimed at optimizing procedures and to develop understanding, while obtaining valuable test data. Additionally, the Non-Standard Tests could serve as a training for a Smith Tool operator if desired. The Non-Standard Tests would:

Develop procedures to clean the pressure vessel and reinstall a sample
- Develop methods for pressurizing the sample and the associated filter cake build-up and spirt loss through the sample
- Experiment with data recording to optimize the data recorded, particularly transducer sampling speed
- Determine practical number of Indentor tests (i.e. data points) per sample face
Perfect Machine Control and optimize machine settings for a given rock type, given insert, and for desired test conditions

T rraTek Systems

FAX Number of pages including this one: 2

February 12, 1997

Smith Tool
P. O. Box 60068
Houston, Texas 77205

Attention: Dr. Sujian Huang

Fax: (281) 233-5900

Phone:

Subject: Single Insert Test System
Reference: Your Fax February 12, 1997

Dr. Huang

You make some very good points in your Fax. I will address them in your order.

- Diameter of the rock sample. We looked at increasing the rock size. The entire system requirements, and thus the cost, escalate 'exponentially' with any increase in the pressure vessel ID. The main constraint is an 8 inch bore pressure vessel is the largest we can fit inside the existing machine frame we are proposing to use. Building a new machine frame would be a significant increase in budget. ?
- Pore Pressure. Yes you can manually control pore pressure. There will be a hand valve and small gage on the end of the pore pressure output line. Other pore pressure controls, such as a manual or servo controlled intensifier, can be easily added later on.
- Actuator size. We can increase the size of the actuators to apply a higher load. The down side of increasing the load is the speed of the actuator, or insert penetration rate, decreases. If make we the hydraulic actuator Ø6.00 piston and Ø3.00 rod the total dynamic load would be 43,000Lbf. and the net load on the cutter would be 11,000Lbf. Maximum penetration rate of the insert is then 2.7 in/sec.

  We can also increase the torque to ~50,000 in-Lbf. The servo valve on the torque actuator can be increased one size so the maximum rotation rate would be 30 Degrees/Sec.

TerraTek Systems

Bottom Actuator. It was our initial intent to use the large actuator as part of this system for reasons you mention. However, we changed to the proposed configuration because the large actuator will not provide the performance required for the insert tests. The large load capacity reduces the penetration rate significantly. Also the actuator is not 'double rod end" so the torque actuator cannot be connected on the rear of the actuator. Mounting the actuators together like we have them configured eliminates the need for thrust bearings and spline connections that are required in other bi-axial loading designs.

I hope this answers your questions. Let me know if you would like more detail or think of any other points. I think it very important and recommend we have a meeting after the design is in its preliminary stage and go over the machine details at that time.

Please give me a call tomorrow (Thursday), or I will call you, and we can discuss these items.

Sincerely,

RMG

Robert Griffin PE
Senior Manager

University Research Park • 400 Wakara Way • Salt Lake City, UT 84108 USA

T rraT k Systems

FAX Number of pages including this one: 2

February 17, 1997

Smith T ol
P. O. Box 60068
Houston, Texas 77205

Attention: Dr. Sujian Huang

Fax: (281) 233-5900 Phone: (281) 233-5890

Subject: Single Insert Test System

Dr. Huang

I have reviewed the items we discussed last Friday regarding modifications to the proposed Single Insert Test System. Let me go through the specific changes we propose:

- Pressure vessel inside bore. As we discussed, if the pressure vessel bore is increased, the outside diameter will also increase and the pressure vessel not fit the used load frame we had proposed. If we use a new a new load frame a Ø10.0 inch bore pressure vessel can be provided.
  A new load frame will also have the advantage of using our pre-stress rod and column design. This design will make the overall frame much stiffer and more precisely aligned. It is the design we currently use on our new Triaxial Test Systems. The test setup and specimen access can also be improved with the new load frame. The new load frame and pressure will greatly improve the overall versatility of the test system and is a good addition to make to the system.

- Bottom Actuator. We looked at increasing the size of the upper hydraulic actuator so it can do the loading for triaxial tests and universal testing as well as the single insert tests. Increasing this actuator size causes a significant decrease in the actuators dynamic performance. This is because as the servo valve and other hydraulic components increase in capacity, there performance characteristics decrease significantly.
  For example the servo valve proposed for the current axial load actuator is a 15gpm rated valve. Its 'blocked port' rise time is ~12msec and its natural frequency is 150Hz. If a single large hydraulic actuator were used a 60gpm valve would be required. This valve has 'blocked port' rise time is ~28msec and its natural frequency is 65Hz. This reduced performance would not only compromise the dynamic response of the system for insert tests, but the 'static stability' would also decrease. This would cause increased drift and decreased resolution of the system during static loading conditi ns such as during triaxial test.
  By using a new loading frame and pressure vessel we can design the system so the

TerraTek Systems

change over from insert testing to other tests is very straight forward. The only change required to change from an insert test to a triaxial compression test would be to remove the internal instrumentation and loading adapters for the insert test from the pressure vessel and install the instrumentation and adapters for a triaxial rock test.

The specifications and cost for these two modifications are the following.

- Increase the bore of the pressure vessel to Ø10.0 inch.
- New, increased size, load frame to accommodate the larger pressure vessel. The load frame will be a pre-stress rod and column design. Load capacity of the frame will be 1,000,000Lb.

Cost .... $ 42,100.

- Add a servo controller, servo valve and transducers to the lower actuator so it can be used for triaxial tests and universal testing applications. Hydraulic and electrical connections will also be included.
- Reconfigure the layout of the load frame and pressure vessel so the lower actuator can be used without a significant change in the systems configuration.
- Include a load cell and set of axial and transverse cantilevers for triaxial compression tests. Add electrical feed throughs to the pressure vessel's lower plug for the additional instrumentation. Add a loading piston to the lower vessel plug so the lower hydraulic actuator can load specimens during triaxial tests.
- Provide the TerraTest™ rock mechanics software on the computer to perform triaxial compression tests.

Cost .... $ 55,400.

The increased pressure vessel size and loading frame need to be part of the initial project. The other option can be added on at any time.

Just as a planning note. We offered a 4 month delivery on this system based upon an estimate that design would begin in the March to April period of this year. If the order is delayed past this time it will begin to compete with a large CT-Flow system we will be designing at that time. There will be a need to allocate resources at that time so the delivery period for the system would probably have to change from 4 to around 6 months.

I know this does not incorporate all the changes we had discussed on the phone but I think it does provide good performance for all the different test requirements you have. Please let me know what you think of this compromise.

Sincerely,

Robert Griffin PE
Senior Manager

SMITH TOOL

A Business Unit of Smith International, Inc.

To: Bob Griffin
Terra Tek, Inc.

cc: Chris Cawthorne, Sidney Green,
Alan Black

From: Sujian Huang
Smith Tool

Date: February 12, 1997

Subject: Single Insert Test System

Bob:

Thanks for sending me the proposal. I have read it very carefully and have the following thoughts/comments:

- The diameter of the rock samples seems a little too small. Is it possible to increase the maximum sample diameter up to 10" and the maximum radius for inserts up to 4" ?
- My understanding is that, right now we do not control pore pressure(which is zero). Can we treat the pore pressure the same way as we do for the confining pressure(meaning manually control and build up pore pressure)?
- The loading capacities for both axial and side loading seem not to be adequate. I am concerned that at confining pressure 10,000 psi, 5000 lbs of force may not be enough to push the insert into the rock. I would like to have 10,000 lbs of axial load to the insert(at full confining pressure) and 50,000 in-lbs for torque loading.
- I would like to use the actuator at the bottom(with capability of 160,000 lbs) for the insert's axial loading. I am thinking to eliminate the separate axial loading actuator for the single insert's indentation at the top. With this, the machine is more universal for other general testing purposes, including single insert and triaxial tests, without further modifications.

Would you please let me know if the above items are doable or too much out of the line? What will be the cost consequence because of these requirements? I can come to Terra Tek to discuss these with you if you think it is helpful.

Thank again for the proposal.

TerraTek yst ms

FAX Number of pages including this one: 2

February 26, 1997

Smith Tool
P. O. B x 60068
Houston, Texas 77205

Attention: Dr. Sujian Huang

Fax: (281) 233-5900 Phone: (281) 233-5890

Subject: Single Insert Test System

Dr. Huang

Per our discussion this week I checked the specifications on the rotary hydraulic actuator for the single insert tester and it will have a maximum rotation of 280°. This was the largest rotation I could find for a rotary actuator. It should be adequate for this testing application.

Sincerely,

RMG

Robert Griffin PE
Senior Manager

TerraTek

TerraTek Inc.

February 4, 1997

Dr. Sujian Huang
Smith Tool
P.O. Box 60068
Houston, Texas 77205 e-mail sjhuang@smith-intl.com

SUBJECT: **Single Insert Test System**

Dear Dr. Huang:

As you are aware Dr. Zheng has moved to Houston; and, he and Mr. Bob Griffin spent a week in China before ZZ left. Therefore, we have been slower to complete your Proposal than anticipated. Bob Griffin who is Head of Terra Tek Systems will be the focal point for your *Single Insert Test System*. I will work with you and Bob to insure maximum communication, and we can of course communicate with ZZ since he continues to be a good friend of Terra Tek.

Bob Griffin was affiliated with Terra Tek nearly at the founding of the Company, and was involved in triaxial rock testing over twenty-five years ago. He has been involved with servo-mechanical control systems his entire career. We also will draw on the expertise of Mr. Alan Black and the Drilling Research Laboratory Staff as appropriate. Alan has much expertise with drilling testing and single cutter testing.

We are proceeding with details for your Test System as follows.

Test System

We are planning to adapt one of the Terra Tek "Creep Machines" which is shown on the attached photograph. The specifications for this machine will be changed to fit this application. For example, we have included a new vessel to give a bigger I.D. We would provide all new electronics—from the servo-valve on; and this would be our latest electronics and digital control software.

We have included a new tension-torsion actuator system (at top of machine) just for the single insert loading. We have kept the large actuator (at bottom of machine) that could be used for triaxial testing at some later date (by adding a servo-valve and certain base plug components that would

need to be fabricated). This makes the machine much more versatile, with applications for future work.

We would include in the original machine design an analysis of concepts for the "third" motion—rocking of the indentor during axial motion and torosional movement. This could then be added at a later date if you desired, and felt such testing would be cost effective.

We are keeping the System Budget to $200,000, not including shipping (or computer).

Testing at Terra Tek

We are proceeding to develop the Budget for testing at Terra Tek. I will complete this and include to you within the next few days.

The testing at Terra Tek would offer the opportunity for us to develop the details of testing procedures, and particularly the chance to optimize testing. We would learn how the filter cake build-up occurs, how leak-off results with insert/rock interaction, and testing procedures to optimize understanding. We would be able to experiment with sample size, particularly length effect on rock breakage and on filter cake build-up and leak-off. It would also give the chance to try out the Transducer System, and make modifications if such should be necessary. We could experiment with control, including adjusting PID's to achieve maximum speeds (shortest test times) possible.

I believe the testing at Terra Tek would be very cost effective for Smith Tool, and would lead to obtaining much data in a short time. If we can begin with testing at Terra Tek, you will not need to wait the estimated four-month delivery period, plus the shipping and installation time period, and plus the debugging time period you would have to go through at Smith Tool.

We look forward to your response to Bob, Alan, or myself.

Sincerely,
Terra Tek, Inc.

Sidney Green
President

Proposal Sent by Express Mail

Single Insert Test System

TO:

Smith Tool
Houston, Texas
Attn. Dr. S. J. Huang

From:

TerraTek Systems
University Research Park
400 Wakara Way
Salt lake City, Utah USA 84108
Attn. Robert Griffin

801-584-2400
801-584-2406 - FAX
e-mail terratek@terratek.com

February 1997

TerraTek Systems

1. Summary

This is a proposal for a Custom designed Single Insert Test System that will be developed to meet the specific requirements for Smith Tool. TerraTek offers its many years of experience in drilling research and design of experimental equipment as part of this proposal. We are a recognized leader in rock mechanics engineering, testing and equipment development.

The system will be used for studying the cutting characteristics of drill bit inserts on actual rock samples in simulated down hole conditions. The pressure vessel contains the insert and rock sample during the test and will use actual drilling mud as the confining fluid. Loading of the insert is done automatically by programmed servo controlled axial load and torque hydraulic actuators.

The System contains an advanced electronics and computer software for data acquisition, machine control, and reporting of data. Appropriate loads and displacements are monitored. Signals are output to an A/D board that can be installed in a standard [redacted] ?The operator runs a test on the system using software and supporting electronics. The software and electronics consist of TerraTEST™ software, Data Acquisition Card, Signal Conditioners, Transducers, Valve Drivers, Servovalves, cables, and other miscellaneous hardware.

The system is a complete stand alone machine for performing tests on single inserts. It is designed to be versatile and able to be modified as the testing requirements change.

1.1 Insert Motion

This proposal provides for two axis of motion by the insert during the cutting test, axial displacement and rotation. These represent the displacements due to thrust and torque on a drill bit. The rotation of the insert's vertical axis as it cuts can also be of interest. This is to simulate the rotation of the drill bit cones as the entire bit is rotated. An analysis and preliminary design of possible mechanisms to produce this motion will be performed as part of this contract. Details of the design requirements and trade-offs can then be determined for a reasonable cost, and components added at a later time Smith Tool by if desired.

1.2 Triaxial Tests

[redacted]. ? Young modulus, Poisons ratio and compressive strength can be determined. Ultrasonic transducers can also be used to measure acoustic properties which allows in-situ dynamic properties to be determined. Capability to perform elevated temperature tests can also be added. This greatly enhances the versatility of this machine.

1.3 Testing

We recommend testing of actual insert samples be performed on the system while it is at TerraTek, prior to shipment. A test program will allow us to optimize the performance of the machine under actual test conditions. Detailed test set up and take down procedures could also be developed. The data acquisition and data reduction routines could be evaluated. Test data on actual inserts can be obtained as soon as the system is built, within 3 to 3-1/2 months after we receive an order. This eliminates up to several months of time before actual test results can be obtained i.e. time for shipping, installation and user familiarization. [redacted]

T rraT k Systems

2. Technical Description

2.1 Overall Features

TerraTek Systems proposes a Single Insert Test System. The system will apply a Thrust (Axial) load and a Torque load to a single insert while under a high pressure confining fluid. A Rock Sample, mounted in the pressure vessel, will react the insert loading. The pressure vessel will use drilling mud as the confining fluid. This will simulate the actual loading environment of the insert in a down hole condition. As mentioned below a 'filter' cake or barrier of drilling mud is built up on the surface of the rock.

The axial and torque loading actuators will be feedback controlled to provided precise loading of the insert. The tests can be performed with load or displacement feedback. **Control of the machine and acquisition of data during the test will be performed automatically by the systems control software.**

2.2 Loading System

2.2.1 Insert Mounting

The insert will be either **press fit, or welded** into a holding fixture that will be bolted to the loading mechanism. The insert will be positioned at up to a 3 inch radius from the center line of the loading piston. The loading fixture will be simple plate that can be made to accommodate various types and sizes of inserts. A rock sample, up to 7 1/2 inches in diameter by up to 8 inches long will be mounted in the pressure vessel for loading by the insert. Smaller diameter and shorter samples can also be used.

2.2.2 Loading

There will be two independent loading devices. Axial load will be produced by a small hydraulic actuator mounted on the top of the test machine frame. This actuator will apply load to the insert as well as over come the force due to the confining pressure of the test vessel. Another hydraulic actuator for applying a torque load is mounted above the linear actuator and moves with it. The axial and torque load are applied to the insert through a loading piston connected to the end of the axial hydraulic actuator. This allows both loading components to be transmitted to the insert without a thrust bearing or other contact device inside the pressure vessel. In order to achieve optimum dynamic response these actuators are sized to just meet the loading required on the insert.

2.2.3 Confining Pressure

The test vessel can be pressurized with actual drilling mud's to simulate down hole conditions. Pressurization is accomplished with a manual air driven reciprocating pump that uses oil. The oil is connected to one side of a liquid t liquid accumulator. The other side is filled with drilling mud and connects to the pressure vessel. After initially charging the vessel with drilling mud using a small fill pump the accumulator is used to build up the confining pressure.

The vessel lines must be flushed and cleaned with clean water and air after testing to prevent corrosion in the vessel. Drilling mud's must not be highly corrosive and need to remain stable, without mixing, while in the pressure vessel.

2.2.4 Pore Pressure

An essential element to this testing is to achieve a pressure differential between the confining pressure, or down hole pressure, and the pore pressure of the rock. This pressure difference is primarily achieved by producing a 'filter cake' of drilling mud on the top face of the rock. This low permeability barrier has significant effects on the fracturing characteristics of the rock as an insert penetrates it. An output line from the bottom of the rock sample out the vessel is provided. **This line can be used to monitor and control the pore pressure or pore flow of the**

TerraTek Systems

sample. **Also during the insert cutting cycle any transient flow of drilling mud due to a breakthrough of the 'filter cake' on the rock sample can be monitored.**

Part of the test set up will be to pressurize the vessel with drilling mud and build up an adequate 'filter cake' to achieve a high effective stress, i.e. the difference between the confining pressure and the pore pressure (which is zero).

The rock sample is jacketed on the sides to prevent intrusion of fluid. The jacket overlaps onto an end cap that has the pore pressure output line. The difference between the pore pressure and confining pressure produces a large force on the rock sample. The friction between these faces is used to react the torque loading of the insert. **This means no special bonding or slotting is required on the end of the rock to react the torque.** The jacket rock and end cap assembly is positioned on the lower closure of the pressure vessel with a set of alignment pins that transfer the torque into the load frame.

2.3 System Controls

The control and electronics system consists of TerraTek Valve Drivers, signal conditioning, an electronics rack, and interconnection cables. Controls will consist of:

- 2 Electronic Valve Drivers
- Limit Controls for each Valve Driver
- 4 Transducer Signal Conditioner channels
- 2 Servo valves and Clamp valves
- Data Acquisition Card, A/D, D/A

The servo control valve drivers feed back control the axial and torque hydraulic actuators. The electronics controls are mounted in an rack with all interconnection cables to the test machine and data acquisition system provided. The data acquisition card **mounts in a PC computer supplied by Smith Tool.** The A/D on the card digitizes the systems transducer signals and inputs them into the computer. The D/A on the card produces two separate signals that connect to the valve drivers, and command, or move, the thrust and torque actuators. Software as discussed below is provided to set up and operate the data acquisition card.

2.3.1 Valve Driver

TerraTek Systems state-of-the-art Valve Drivers have been specifically designed for use with rock mechanics and materials test systems. They are intended to be used in testing laboratories in quasi-static or dynamic, servo-hydraulic test programs. Two feedback modes are provided on each controller; load and displacement. The transducers as discussed below are used as feedback to the controls.

2.3.2 Limit Controls.

Both the controllers will have a set of limit detectors that will monitor preset values of load and displacement. The system will be stopped in the event a limit is exceeded. This is designed to protect load cells and other test fixtures from accidental damage.

2.3.3 Transducer Signal Conditioners.

Signal conditioners provide regulated excitation voltage to, and amplification of, output signals from instrumentation transducers. High grade amplifiers provide accurate system control and data acquisition. Outputs from these signal conditioners are routed to an output cable and the data acquisition card. This PC board can be plugged into a users PC computer to provide automatic data acquisition. All signal conditioners in the system provide -10 to +10 VDC output signals. Software will provide high speed data acquisition of the test parameters.

2.3.4 Transducers

Four parameters are measured during the test; axial load; torque (or side load on the insert); axial displacement; and rotation of the insert.

TerraTek Systems

Axial and torque loads are measured inside the pressure vessel with a special stain gaged load cell mounted just above the insert. Only the insert loads are measured with this design and effects of confining pressure and seal friction etc. are bypassed. Dynamic load characteristics of the insert can be measured with this load cell.

Axial and rotational displacements are measured with transducers mounted outside the pressure vessel. These transducers will be high output LVDT's with essentially infinite resolution.

2.3.5 Servo Valves and Clamp Valves

High performance servo valves will be used on both axis of control. The valves will provided rapid loading rates and stable control during the test.

As a system damage protection feature, a clamp valve is mounted on the servo valve manifold, isolating the actuator from the hydraulic lines. Activating the clamp valve immediately closes the ports on the actuator and prevents further actuator piston travel. The clamp valve is remotely activated from the Valve Driver, either by a manual switch or by the fail-safe module when any one of four preset limits is exceeded. The clamp valve is also activated on system power failure. The clamp valve helps protect in-vessel instrumentation from overload in case of sample failure or power outage. It also facilitates initial test setup.

The clamp valve is also used during setup of the test to enable switching of feedback channels and to prevent drifting of the hydraulic actuators, especially when operating in load feedback. It is important on the torque channel because it is 'slaved' to the axial channel which allows it to 'drift' significantly during setup.

2.4 Test Control & Data Acquisition

The test system is designed to produce a dynamic modeling of a single drill bit insert as it penetrates a rock sample. Once the physical machine, the controls and the computer program are set up and configured the test is performed automatically. Data from the machine transducers is also acquired during the test and stored for post test analysis.

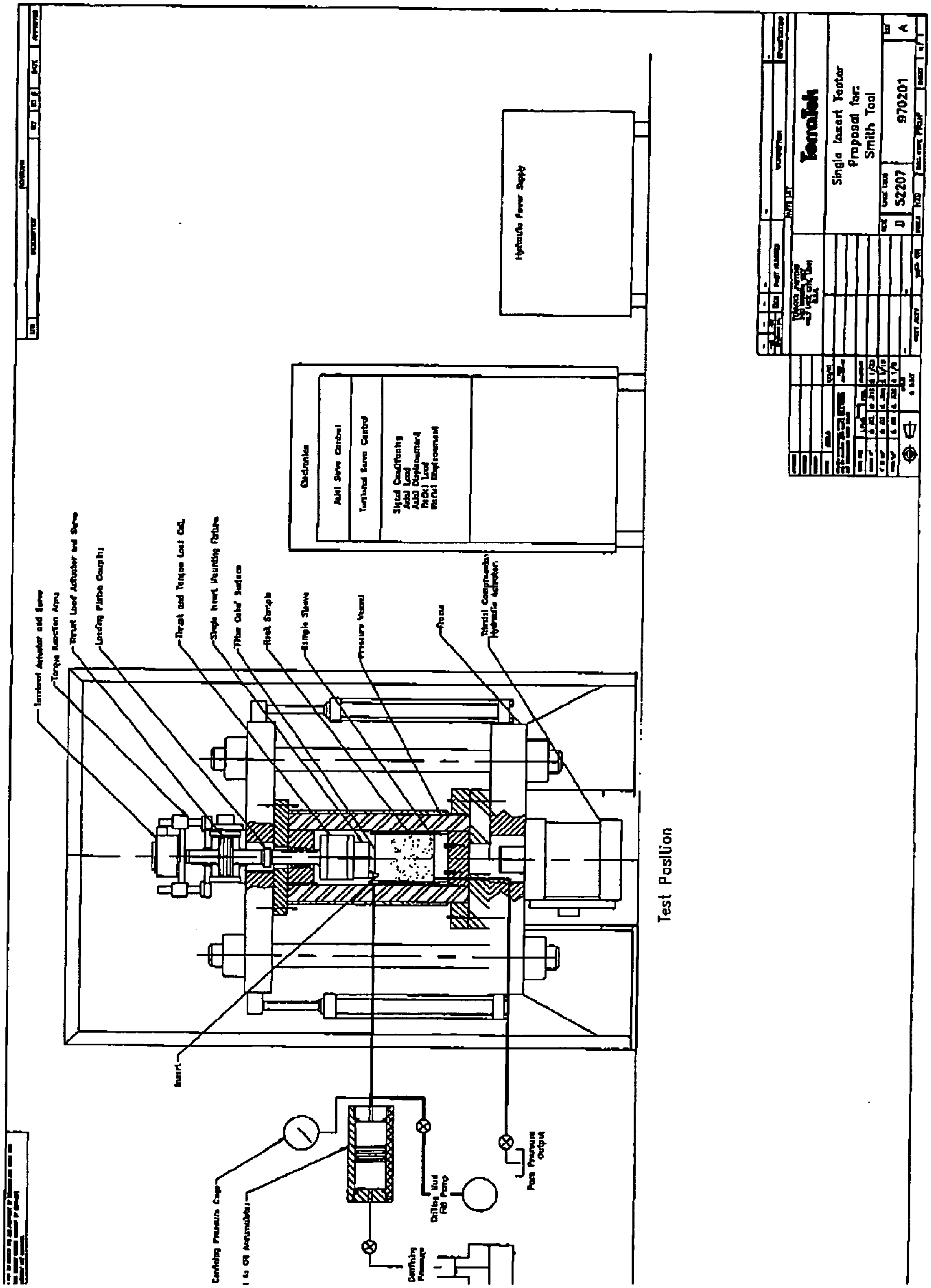
The TerraTEST™ Software will control the test based upon programmed parameters. The Data Acquisition Card provides the digital interface of the software, and computer, to the test machine. There are two functions the data acquisition card performs. It converts the analog signals from the transducers into digital data (A/D) and convert the pre-programmed command data from the computer into analog signals (D/A) for controlling the Valve Drivers.

2.5 Test Control

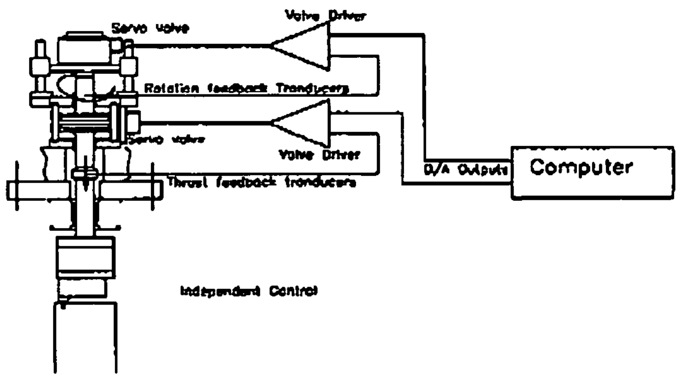
The thrust and torque actuators with this system can be controlled in either an independent and slave mode.

2.5.1 Independent Mode

In independent mode, shown below, the two channels of feed back control are commanded to move by separate output signals for the computer D/A. The computer outputs are time synchronized to develop the appropriate insert thrust and torque cutting profile. Note that the feedback controls for these two channels can either be load or displacement and do not have to be the same. The commands that are created do have to make physical sense and be with in the capabilities of the insert and test machine.


Test Position
Hydraulic Power Supply
Electronics
Axial Servo Control
Torsional Servo Control
TerraTek
Single Insert Tester
Proposal for:
Smith Tool
52207
970201
A

TerraT k Syst ms



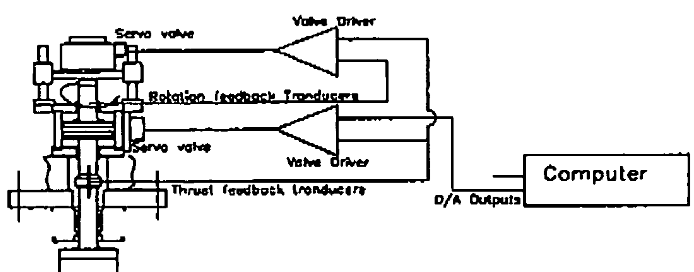
Independent Control

2.5.2 Slave Mode

Slave mode, shown below, operates with the torque actuator controlled by a thrust transducer. The thrust channel is commanded by an output from the computer data acquisition card's D/A. In this mode the torque is in direct response to the thrust, independent of time. Feedback controls for the two channels can also either be load or displacement and do not have to be the same.

In this mode the axial actuator is the primary channel with the torque actuator slaved to the axial channel. With both channels in displacement feedback the insert will penetrate the rock sample at preset rate and at the same time will rotate across the rock face directly proportional to the axial penetration.

In thrust load control a preset load is applied and the insert penetrates the rock as far as required to achieve the load. If the torque actuator is set in load feedback the insert will be rotated until the preset torque is achieved. If the torque actuator is in displacement feedback the insert is rotated a preset angular distance independent of the torque required.



Slave Control

Both modes have advantages for different types of test, and it is possible to set this test system up to operate in either mode. The slave mode can have the advantage of the torque tracking the thrust which means variables

TerraTek yst ms

such as variations in rock properties have less affect on the loads produced. However at higher test rates the physical response of the control system, mainly the servo valve, can limit the ability of the slaved servo to 'keep up'. In this case the independent control mode will provide a simpler and more responsive control system.

2.6 Data Acquisition

TerraTEST™ Software is the interface for computer-controlled testing. It provides the capabilities needed to set up a test program, enter sample information, configure and calibrate transducers, run the test and view the resulting data. TerraTEST™ is a 16-bit, Windows95 based program with a multitude of testing capabilities. A 16-bit Data Acquisition Card for acquisition of up to 8 transducer signals and the ability to control the two servo loops is provided as the software interface to the machine. This basic software is used extensively and is particularly convenient for materials testing. It was developed through TerraTek's more than 25 years of experience using Computer-Controlled, test machines. It is continually improved and enhanced to provide powerful testing capabilities.

TerraTEST™ contains modules for setting up test command profiles, assigning data acquisition channels, entering transducer calibration data, reading transducer zero and shunt voltages, correcting for pressure effects, controlling the test, acquiring transducer data, printing data, and graphically displaying data. Both SI and English units are supported. The Test Setup Module allows the operator to enter test and sample identification information and to define the test type.

- The Channel Assignment Module allows the operator to identify and calibrate various transducers. In general, once this information is set up, it does not change from test to test until a transducer is changed.
- The System Setup Module provides places to enter Pressure Effects, and Load Effects.
- The Pre-Test Module allows the operator to prepare for testing by selecting initial sample rates and taking zeroes and shunt values.
- The Test Control Module executes the test sequence which the operator has selected. Data is stored on disk and can be printed out if desired.

After data is acquired it stored on the computer. Data can be displayed using the routines available with the TerraTest™ software or it may accessed by other Windows programs such as Excel or MathCad for further analysis.

3. Additional Capability

[redacted] *If we have this, no need to separate insert's axial loading actuator.*

This system also has the capability to run a full range of triaxial compression tests on rock samples. A large hydraulic actuator with a load capacity of 160,000 pounds is mounted on the lower platen. This actuator can be connected to the systems servo controls and hydraulics to provide a high load testing system. The load frame and pressure vessel are designed to accept an optional lower end closure, with a loading piston, and internal instrumentation to allow triaxial compression tests to be run with this system.

Other enhancements such as servo-controlled confining pressure and pore pressure can be added to perform additional tests.

TerraTek Systems

4. Machine Specifications

Pressure Vessel

Pressure Rating	10,000 psi
Internal Bore	8 in
Working Length	20 in
Loading Piston Diameter	2 in
Sample Size, Maximum	7 1/2 in Dia. x 8 in long
Temperature	Ambient (Temperature Capability can be added)
Pressure Control	Air Driven Manual Pump

Load Frame — 4-Column Fixed Platen

Load Capacity	800,000Lbf.
Working Height	32 in
Footprint Dimensions	45 x 30 in

Axial Load

Insert Dynamic Loading (at full confining Pressure)	5,000Lbf
Actuator Dynamic Load Rating	36,000Lbf
Actuator Static Load Rating, Maximum	52,000Lbf
Axial Displacement	2 inches
Displacement Rate	3.5 in/sec

Radial Load

Dynamic Torque	9,000in-lbf.
Rotation Angle	45 Degrees
Rotational Rate	80 Degrees/Sec
Insert 'side' load @ 3 in Radius	3,000 Lbf

Servo Valve & Clamp Valve

Servo Valve Response 90° Phase	150Hz
Dynamic Pressure Drop	1000Psi.
Clamp Valve Closing	20 msec.

Hydraulic Power Supply

Pressure	3,200psi
Flow, nominal	5 GPM
Accumulator (For Dynamic Load)	1 Gal.
Reservoir Capacity	20 gallons
Pump	Fixed Displacement
Safety Interlocks	Over pressure High temperature Low fluid level Oil filter
Cooling System (Optional)	Water
Power Requirements	220 or 440 VAC 50/60 Hz

TerraTek Systems

Controls and Data Acquisition

Servo controls	Axial Control Radial Control
Set Point Linearity	±.5%
Frequency Response (-3dB)	10KHz
Signal Conditioning Channels	Axial Load Axial Displacement Radial Load Radial Displacement
Frequency Response -3dB	8Khz.
Signal Outputs, Isolated	±10V
Output Linearity, Absolute	±0.5%
Gain (Strain Gage)	1000v/v Max.
Carrier Frequency, 20Hz-20KHz	2.5KHz Standard
Excitation Voltage, .2-20V	2.5V Standard
Harmonic Distortion	-50dB
Data Acquisition Card	16 Bit
Data Acquisition Rate, per channel	100,000 Samples/Sec.
Bus Interface	PCI
A/D Channels	8
D/A Channels	2
Operating System	Windows95
Computer, Minimum	Pentium, 100MHz
Limit Detector Accuracy	±1.0%
Frequency Response	100KHz.

T rraTek Systems

5. Support Services

5.1 Check out

The system will be fully assembled and checked out at TerraTek. Tests on actual inserts and rock samples will be performed. This check out could also provide a period of training for the customer on the system.

5.2 Installation/Training

TerraTek will send qualified engineers to the customers facility to complete the installation. Complete installation can be accomplished in three working days.

5.3 Warranty

TerraTek will provide its standard one year warranty, a copy is attached. Warranty period shall begin upon completion of the installation, or thirty days after delivery, whichever shall occur sooner.

6. Budget

<u>Single Insert Test System</u>

Including Load Frame, Hydraulic Power Supply, Triaxial Test Cell, Base Closure, Load Cell and End Caps, Drilling Mud Confining Pressure System, Valve Drivers, Signal Conditioners, Computer A/D board with Data Acquisition Software.

Total Cost $ 200,000.

This offer shall be good until April 5, 1997.

6.1 Terms

This is a firm fixed price offer. A copy of the general terms and conditions are attached.

Payment terms are the following

- 20% With Purchase Order
- 70% Upon completion of check out at TerraTek.
- 10% Upon completion of installation

6.2 Delivery

The Single Insert Test System will be ready to ship within four months after receipt of order. Shipment will be FOB TerraTek, Salt Lake City, Utah.

TERRATEK PRODUCTS DIVISION
TERRATEK, INC.
Salt Lake City, Utah

GENERAL TERMS AND CONDITIONS OF SALE

Unless otherwise agreed to in writing, TerraTek, Inc. sells its equipment in accordance with the following provisions:

1. **PRICE:** Quoted prices are subject to change prior to acceptance of order by Seller.

2. **TAXES:** No Federal, State, or local taxes on the purchase, sale, or use of the equipment are included in the quoted prices. If any such taxes are applicable, they shall be for the account of the Purchaser.

3. **ITEMS INCLUDED:** Each sale includes only the equipment described in the order.

Responsibility for proper operation of equipment if not installed by Seller or in accordance with its instructions rests entirely with Purchaser.

Seller will supply only the safety devices, if any, described in the order and will comply with provisions of the Occupational Safety and Health Act of 1970, applicable to equipment as manufactured by TerraTek. Seller shall not be responsible for compliance with state or local construction codes or safety and health statutes unless Seller has accepted such responsibility in writing.

4. **SECURITY INTEREST:** Seller retains title and right of repossession to the equipment until the full purchase price has been paid. Purchaser will not encumber nor permit others to encumber said equipment by any liens or security instruments.

5. **SHIPMENTS AND DELIVERY:** Seller shall use reasonable efforts to meet specified delivery dates, but such dates are estimates only and not guaranteed. So long as Seller makes reasonable effort to complete manufacture and shipment, it shall have no liability, direct or indirect, for any delay in delivery and may not be declared in breach nor shall the order be subject to cancellation. In any event, delivery is based upon the effective date of the order and subject to prompt receipt by Seller of all necessary information and instructions from Purchaser, including any required approval of drawings.

Seller may make partial shipments, and invoices therefor shall be payable in accordance with their terms.

Purchaser shall inspect the equipment and notify Seller of any damage or shortage within seven days of receipt. Failure to so notify Seller shall constitute acceptance, relieving Seller of liability for damage or shortage.

6. **SELLER WARRANTS EQUIPMENT OF ITS MANUFACTURE ONLY IN ACCORDANCE WITH ITS CURRENT APPLICABLE TERRATEK WARRANTY AGAINST DEFECTS IN WORKMANSHIP AND MATERIALS (FORM TTS-002), WHICH WARRANTY IS INCORPORATED BY REFERENCE AND MADE A PART HEREOF.**

7. **PATENTS:** Seller agrees that it will defend and save harmless Purchaser against proceedings, or damages arising therefrom, alleging that Seller's equipment infringes any apparatus claim of a United States Patent existing as of date of order, provided Seller is given prompt notice of such proceedings, is accorded full control of the defense, settlement, or compromise thereof, and Purchaser furnishes Seller, on request, all needed information, assistance, and authority to enable Seller so to defend. Seller will reimburse Purchaser for actual out-of-pocket expenses, exclusive of legal fees, incurred in rendering assistance at Seller's request. The foregoing states the entire liability of Seller with respect to patent infringement.

8. **CANCELLATION, SUSPENSION, OR DELAY:** If Purchaser requests or causes a cancellation, suspension, or delay of Seller's work, Purchaser shall pay Seller all appropriate charges incurred up to the date of such event plus Seller's overhead and reasonable profit. Additionally, all charges related to and risks incidental to storage, disposition, and/or resumption of work, shall be borne solely by Purchaser.

9. **LIMITATION OF LIABILITY:** Seller shall not be liable for incidental or consequential damages for any reason whatsoever.

10. **CHANGES AND BACKCHARGES:** Seller shall not be obliged to make changes in or additions to the scope of work unless Seller agrees thereto in writing and an equitable adjustment is made to price and/or delivery.

Seller will not approve or accept returns of or backcharges for labor, materials, or other costs incurred in modification, adjustment, service, or repair of equipment unless previously approved in writing by an authorized employee of Seller.

11. **CHANGES IN DESIGN:** Seller reserves the right to modify the design and construction of equipment in order to incorporate improvements or substitute material equal or superior to that originally specified. No charge shall be made to Purchaser for modifications made at Seller's option.

STANDARD WARRANTY

Equipment manufactured, refurbished, or repaired by TerraTek, Inc. ("TERRATEK or "TerraTek") is backed by the following warranty:

For the benefit of the original user, TerraTek warrants all new or refurbished equipment or integrated systems manufactured by it or TerraTek repaired components to be free from defects in material and workmanship; and will replace or repair, F.O.B. its factories or other location designated by it, any part or parts returned to it by user, which examination shall show to have failed under NORMAL USE AND SERVICE by the original user within the specified warranty period following initial shipment by TerraTek. Such repair or replacement shall be free of charge except for those parts such as seals, transistors, tubes, fluids and the like that are consumable and normally replaced during maintenance. TerraTek's obligation under this warranty is conditioned upon its receiving prompt notice of claimed defects which shall in no event be later than thirty (30) days following expiration of the specified warranty period and is limited to repair or replacement as aforesaid.

THIS WARRANTY, INCLUDING THE STATED REMEDIES, IS EXPRESSLY MADE BY TERRATEK AND ACCEPTED BY PURCHASER IN LIEU OF ALL OTHER WARRANTIES, INCLUDING WARRANTIES OF MERCHANTABILITY AND FITNESS FOR PARTICULAR PURPOSE, WHETHER WRITTEN, ORAL, EXPRESS, IMPLIED, OR STATUTORY. TERRATEK NEITHER ASSUMES NOR AUTHORIZES ANY OTHER PERSON TO ASSUME FOR IT ANY OTHER LIABILITIES WITH RESPECT TO ITS EQUIPMENT. TERRATEK SHALL NOT BE LIABLE FOR NORMAL WEAR AND TEAR, NOR FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGE DUE TO INOPERABILITY OF ITS EQUIPMENT FOR ANY REASON NOR ON ANY CLAIM THAT ITS EQUIPMENT WAS NEGLIGENTLY DESIGNED OR MANUFACTURED.

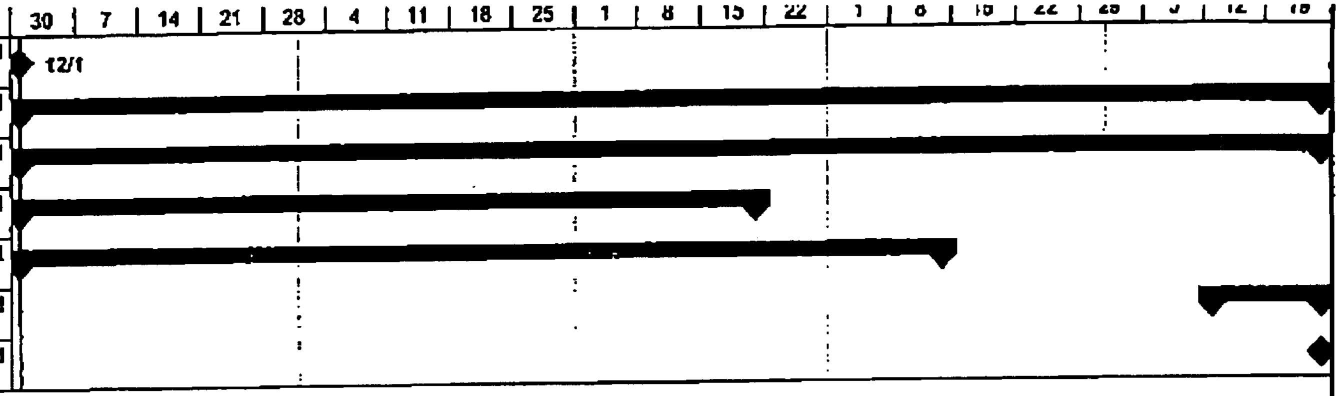
This warranty shall not apply to equipment or parts thereof that have been altered or repaired outside of a TerraTek's factory, or damaged by improper installation, application, erosion, or corrosion of any sort, or subjected to misuse, abuse, neglect or accident.

TerraTek makes no warranty with respect to parts, accessories, or components manufactured by others. The warranty applicable to such items is that offered by their respective manufacturers.

TERRATEK, INC.
SALT LAKE CITY, UTAH

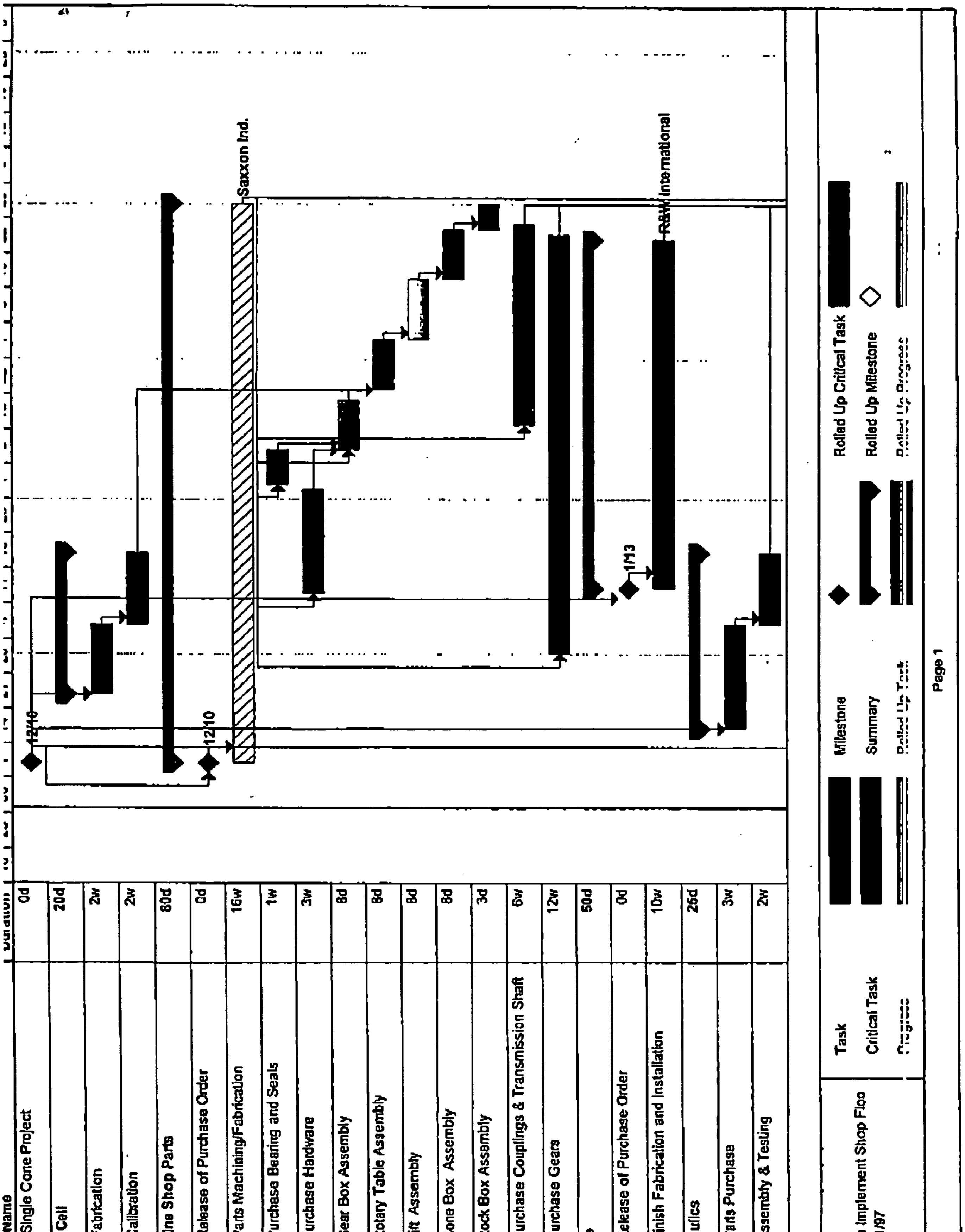
1997

ID	Task Name	Duration
	START PROJECTS	0d
	Start Bldg. Exp/Mod Project	105d
	Single Con Tester	105d
	Flow Visualization	60d
	Single Insert Tester	75d
	Drill Rig	10d
	END PROJECTS	0d

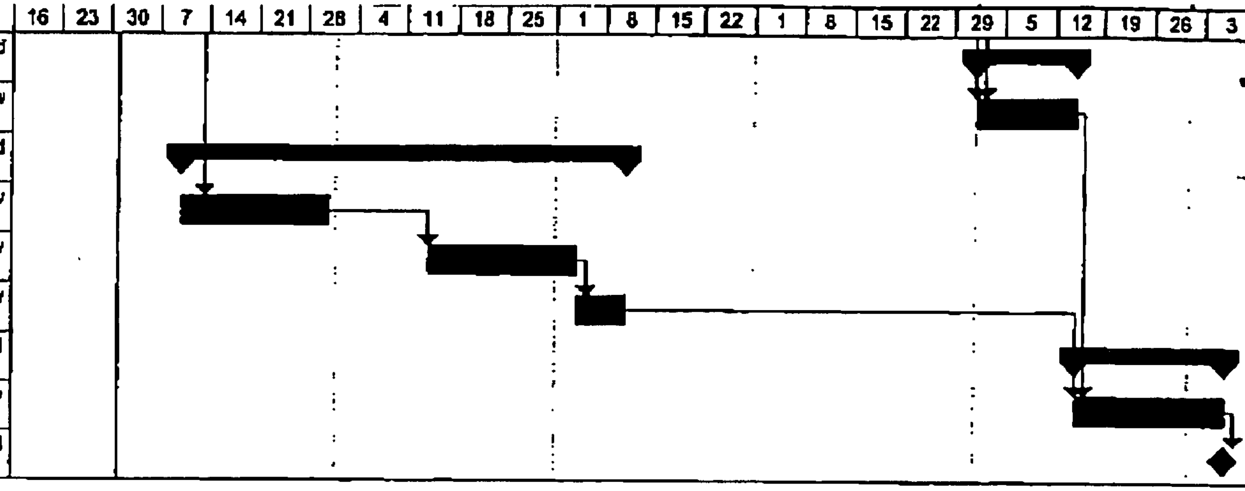


t: Total.MPP
Mon 12/1/97

Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress


Task Name
Duration
Single Cone Project 0d
d Cell 20d
Fabrication 2w
Calibration 2w
hine Shop Parts 80d
Release of Purchase Order 0d
Parts Machining/Fabrication 16w
Purchase Bearing and Seals 1w
Purchase Hardware 3w
Gear Box Assembly 8d
Rotary Table Assembly 8d
Lift Assembly 8d
Cone Box Assembly 8d
Rock Box Assembly 3d
Purchase Couplings & Transmission Shaft 6w
Purchase Gears 12w
ne 50d
Release of Purchase Order 0d
Finish Fabrication and Installation 10w
raulics 25d
Parts Purchase 3w
Assembly & Testing 2w
12/10
12/10
Saxxon Ind.
1/13
R&W International
to Implement Shop Floo
/1/97
Task
Critical Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Critical Task
Rolled Up Milestone
Rolled Up Progress
Page 1

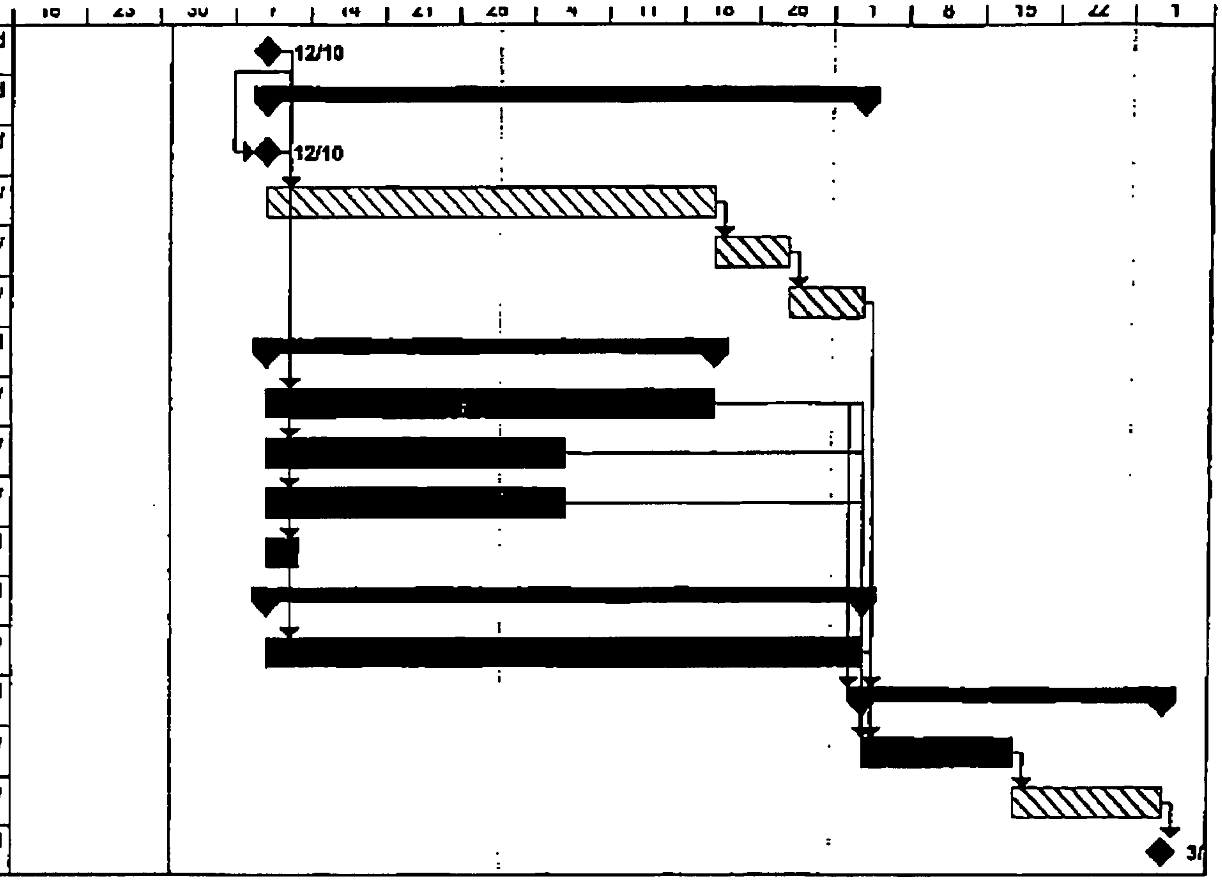
Task Name	Duration
ain Assembly	10d
Complete Assembly	2w
ontrol System	45d
Design & Parts Purchase	3w
Parts Purchase & Assembly	3w
Testing	1w
iplementation	15d
Testing & Calibration	3w
id Single Cone Project	0d



n to Implement Shop Floo
12/1/97

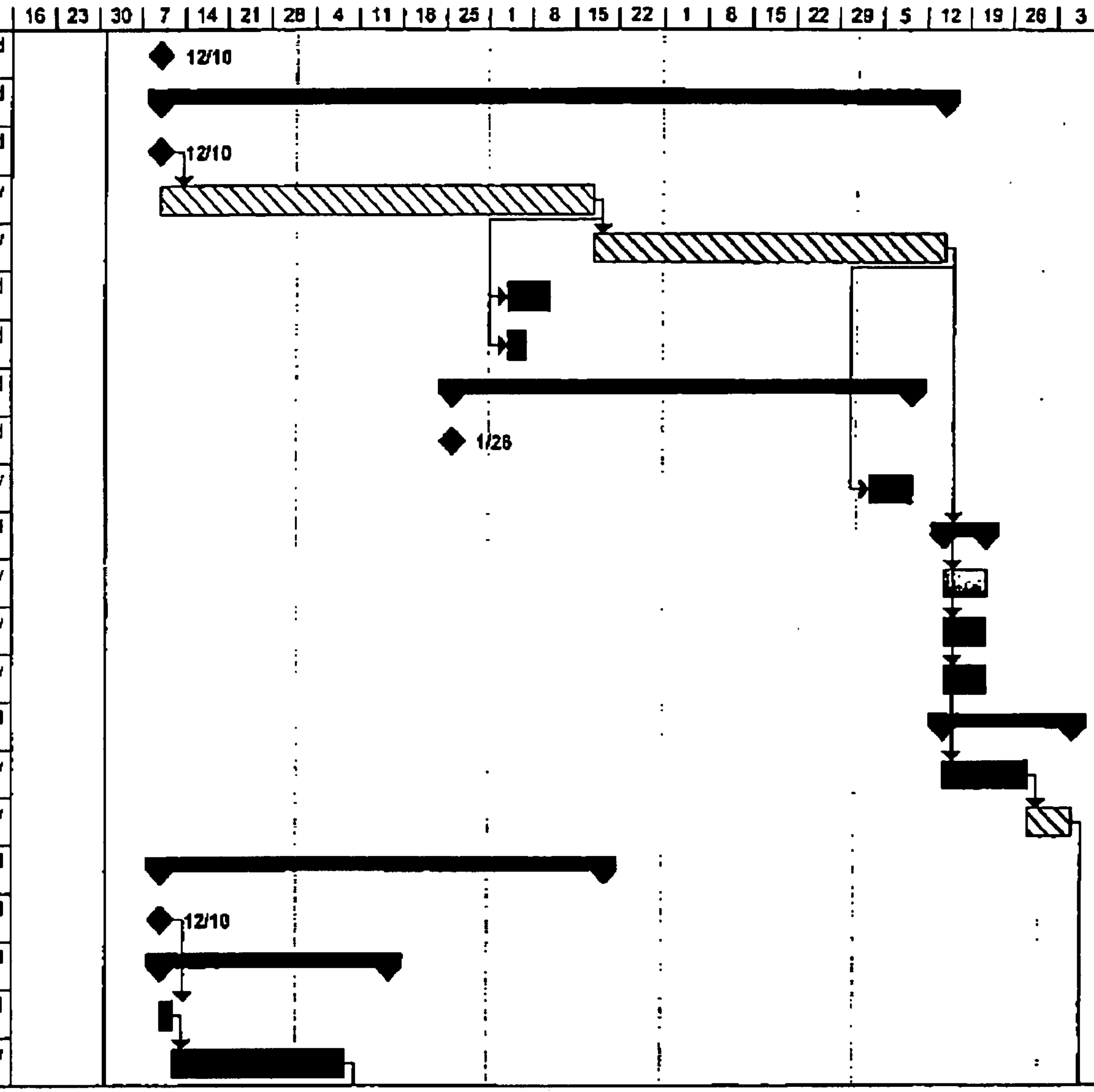
Task	Milestone	Rolled Up Critical Task
Critical Task	Summary	Rolled Up Milestone
Progress	Rolled Up Task	Rolled Up Progress

Task Name	Duration
...t Flow Visualizer Project	0d
...hine Parts Fabrication	40d
Release of Purchase Order	0d
Parts Machining/Fabrication	6w
Sub- Assembly 1	1w
Sub Assembly 2	1w
...hase Items	30d
Item 1	6w
Item 2	4w
Item 3	4w
Hardware	3d
...ne Fabrication	40d
Fabrication & Installation	8w
...embly & Testing	20d
Equipment Assembly	2w
Testing & Calibration	2w
...ct Finish	0d



...to Implement Shop Floo ...1/97	Task		Milestone		Rolled Up Critical Task	
	Critical Task		Summary		Rolled Up Milestone	
	Progress		Rolled Up Task		Rolled Up Progress	

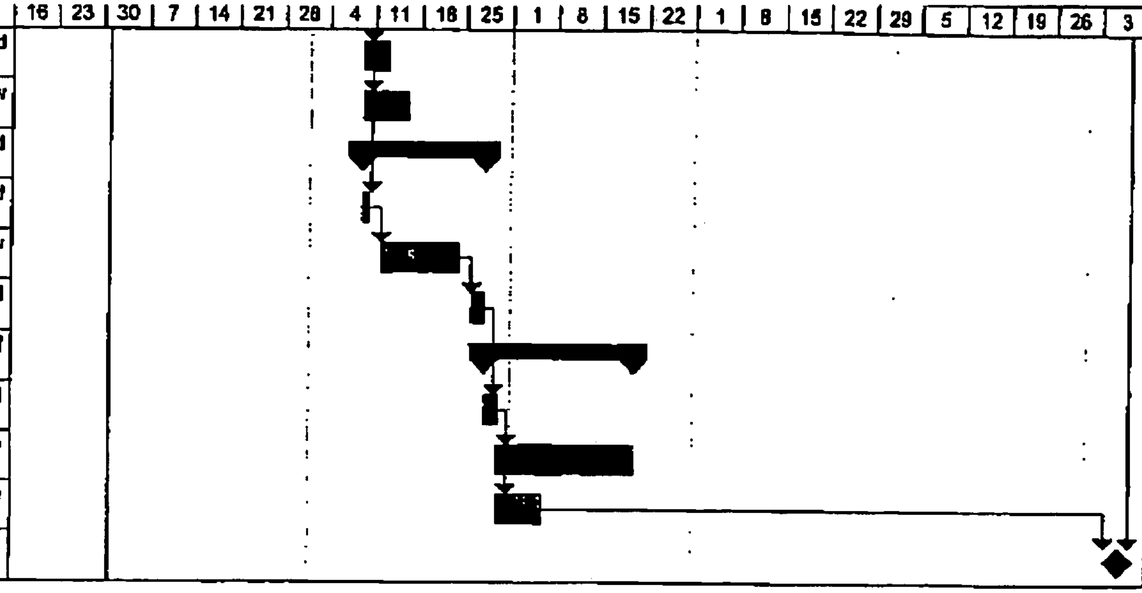
ID	Task Name	Duration
	Start Bldg. Expansion/Modificalton Project	0d
	Building Expansion	90d
	Release of Purchase Order	0d
	Off-Site Construction	10w
	On-site Construction	8w
	Move of Trailer Facility	5d
	Move Bits	3d
	Electrical Power Modification	54d
	Submit Requisition	0d
	Implement Power Upgrade	1w
	Move Equipment Into New Building	5d
	Hammer Bit Division	1w
	Welding Division	1w
	Machine Shop	1w
	Elastomer Division	15d
	Construction	2w
	Move Equipment & Set up	1w
	Shop Floor Modification	52d
	Release of Purchase Order	0d
	Tecnicians Offices & Control Room	27d
	Move Machine Tools	2d
	Construction Process	4w



: Plan to Implement Shop Floo
ton 12/1/97

Task
Critical Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Critical Task
Rolled Up Milestone
Rolled Up Progress

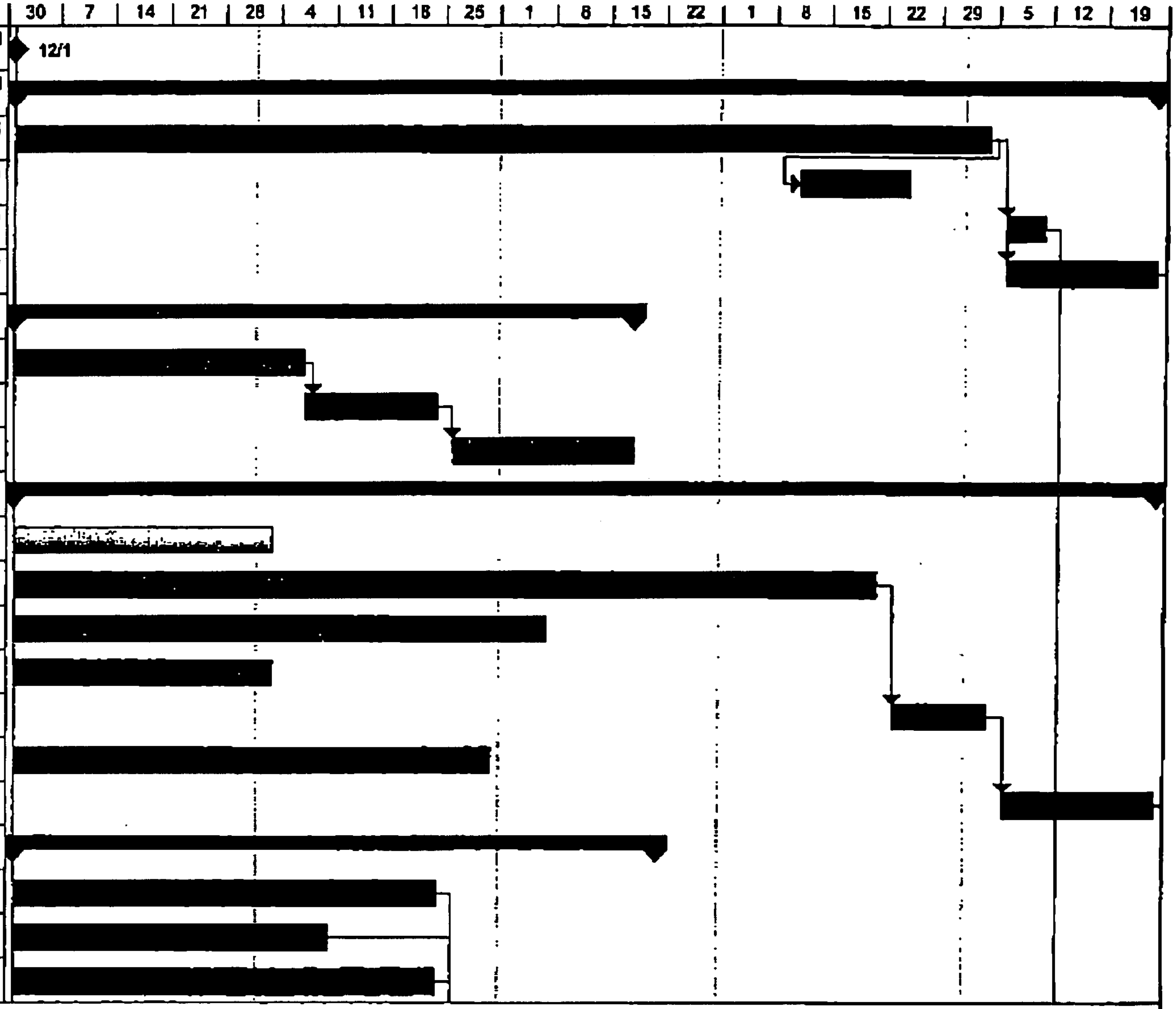
ID	Task Name	Duration
	Move Technician Offices	2d
	Move Data Acquisistion Systems	1w
	Furnace Room	13d
	Move Furnaces accessories	1d
	Construction Process	2w
	Move Back Funaces & Accessories	2d
	Physical Laboratory & Offices	17d
	Move Material Test Equipments	2d
	Construction Process	3w
	Electrical Redo for Material Test Equi	1w
	End Building Expansion/Modification	0d



: Plan to Implement Shop Floo
tion 12/1/97

Task	Milestone	Rolled Up Critical Task
Critical Task	Summary	Rolled Up Milestone
Progress	Rolled Up Task	Rolled Up Progress

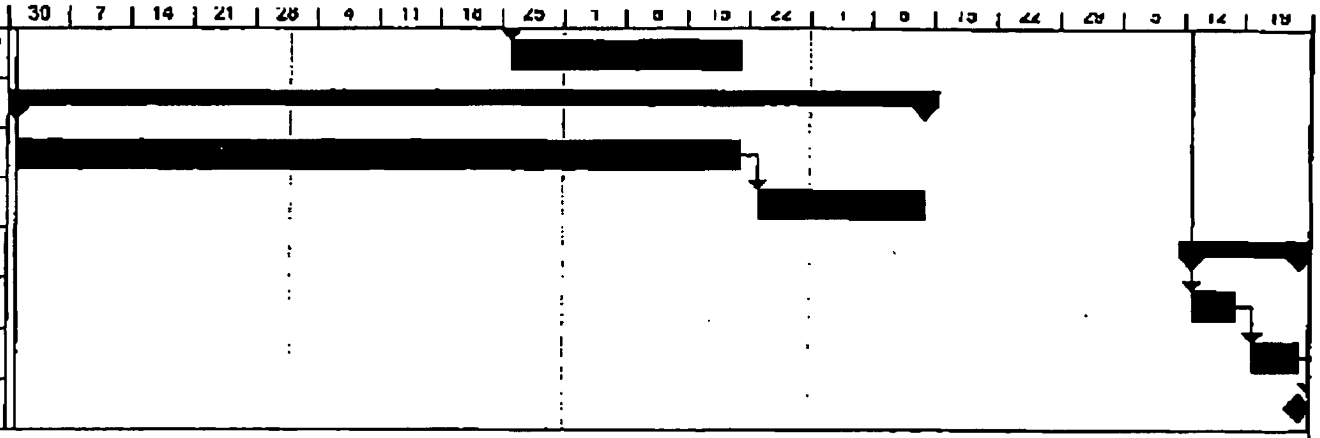
ID	Task Name	Duration
	START PROJECTS	0d
	Start Bldg. Exp/Mod Project	105d
	Building Expansion	90d
	Electrical Power Modific	2w
	Move Equip. into New Bl	1w
	Elastomer Division	3w
	Shop Floor Modificatio	57d
	Techs Off. & Contro	27d
	Furnace Room	13d
	Pysical Lab & Office	17d
	Single Cone Tester	105d
	Load Cell	5w
	Machine Shop Parts	16w
	Frame	10w
	Hydraulics	5w
	Main Assembly	2w
	Control System	9w
	Implementation	3w
	Flow Visualization	60d
	Machine Shop Parts	8w
	Purchase Items	6w
	Frame Fabrication	8w



: Total.MPP
lon 12/1/97

Task — Progress — Milestone — Summary — Rolled Up Task — Rolled Up Milestone — Rolled Up Progress

ID	Task Name	Duration
	Assembly & Testing	4w
	Single Insert Tester	75d
	Fabricationby TerraTek,	12w
	Implementation & Testin	3w
	Drill Rig	10d
	Relocation	1w
	Implementation & Testin	1w
	END PROJECTS	0d



: Total.MPP
Ion 12/1/97

Task		Summary		Rolled Up Progress	
Progress		Rolled Up Task			
Milestone		Rolled Up Milestone			

PROJECTS UPDATE MEETING

Prabhakaran Centala

DATE: MARCH 23, 1998

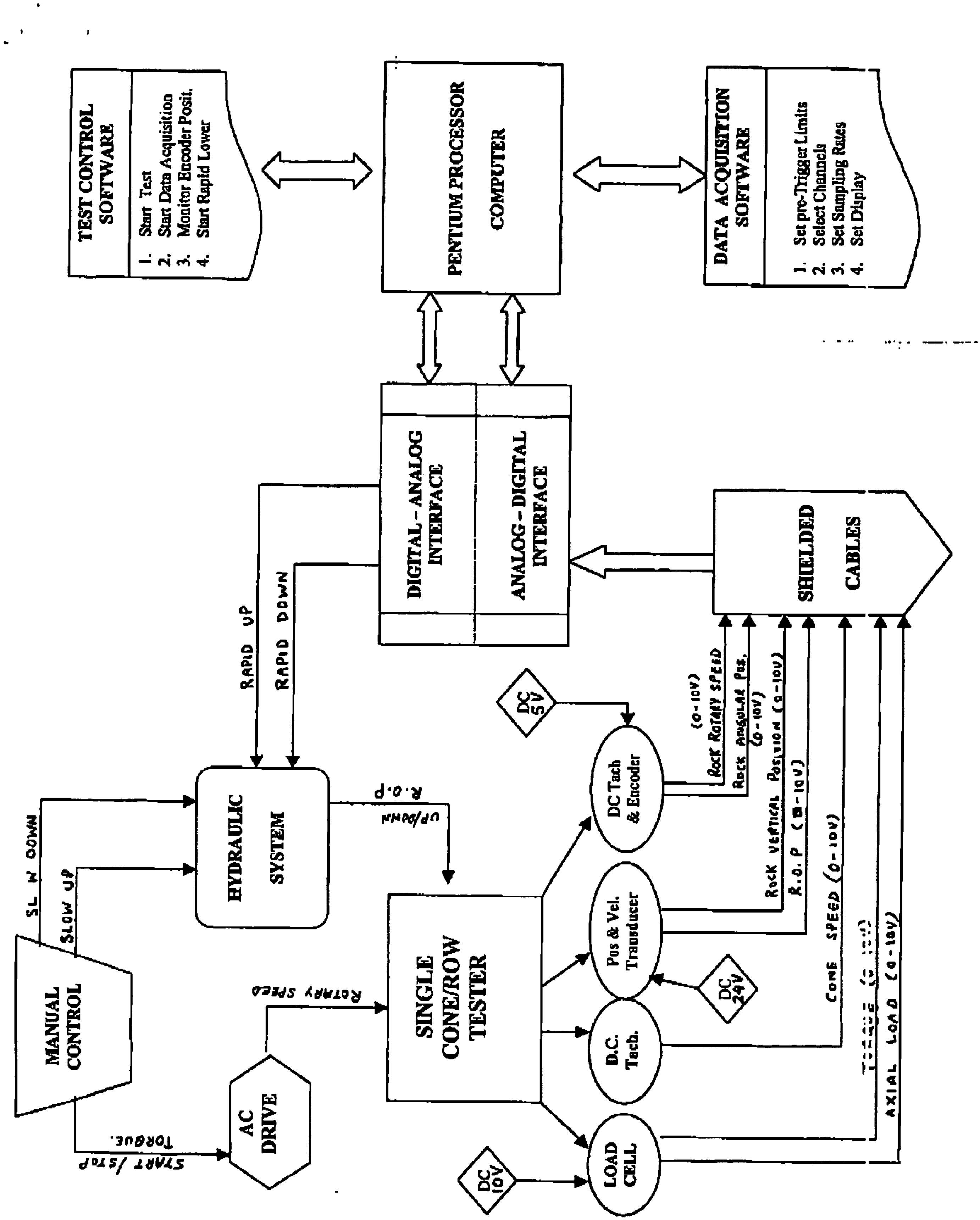
PLACE: SMITH TOOL CONFERENCE ROOM

AGENDA

1. UPDATE ON SINGLE CONE TEST EQUIPMENT - COMPONENTS/FRAME FABICATION
2. CONTROL & DATA ACQUISITION INSTRUMENTATION FOR SINGLE CONE TEST EQUIPMENT
3. UPDATE ON SINGLE INSERT TEST EQUIPMENT
4. UPDATE ON THE NEW ENGINEERING BUILDING

SINGLE CONE TEST EQUIPMENT- COMPONENTS/FRAME FABICATION

1. **SAXON INDUSTRIES**
   1.1. MANUFACTURING THE EQUIPMENT COMPONENTS
   1.2. PROGRESS IS SATISFACTORY
   1.3. UPDATES/CHANGES MADE ON AS-ON-NEED BASIS
2. **R & W INTERNATIONAL**
   2.1. FABRICATING THE FRAME ASSSEMBLY
   2.2. PROGRESS IS SATISFACTORY
   2.3. CHANGES MADE UPON PROBLEM IDENTIFICATION.


TEST CONTROL SOFTWARE
1. Start Test
2. Start Data Acquisition
3. Monitor Encoder Posit.
4. Start Rapid Lower
PENTIUM PROCESSOR COMPUTER
DATA ACQUISITION SOFTWARE
1. Set pre-Trigger Limits
2. Select Channels
3. Set Sampling Rates
4. Set Display
DIGITAL - ANALOG INTERFACE
ANALOG - DIGITAL INTERFACE
SHIELDED CABLES
RAPID UP
RAPID DOWN
HYDRAULIC SYSTEM
SL W DOWN
SLOW UP
MANUAL CONTROL
TORQUE
START /STOP
AC DRIVE
ROTARY SPEED
SINGLE CONE/ROW TESTER
R.O.P
UP/DOWN
DC 5V
DC Tach & Encoder
(0-10V) ROCK ROTARY SPEED
ROCK ANGULAR POS. (0-10V)
ROCK VERTICAL POSITION (0-10V)
R.O.P (0-10V)
CONE SPEED (0-10V)
AXIAL LOAD (0-10V)
Pos & Vel. Transducer
DC 24V
D.C. Tach.
LOAD CELL
DC 10V

CONTROL & DATA ACQUISITION INSTRUMENTATION FOR SINGLE CONE TEST EQUIPMENT

A. PROPOSED PRELIMINARY TEST SET-UP

1. LOAD ROCK INTO ROCK BOX AND CLAMP IT
2. MOUNT DESIRED CONE/CONE ROW ON TESTING SPINDLE
3. MOUNT EXTERNAL PAIR OF GEARS TO GEARBOX SO AS TO OBTAIN DESIRED CONE-TO-ROCK SPEED RATIO.
4. PRE-SET LIMIT SWITCHES FOR
   - 4.1. MAXIMUM VERTICAL ROCK DISPLACEMENT POSITION
   - 4.2. TEST START/STOP POSITION
5. START DATA ACQUISITION PROGRAM; ASSIGN DATA CHANNELS WITH APPROPRIATE TRIGGER LEVELS AND SET SAMPLING RATES.
6. CHECK ALL TRANSDUCER CONNECTIONS

B. PROPOSED TEST PROCEDURE

1. START HYDRAULIC PUMP
2. OPERATE RELAY TO SLOW RAISE ROCK SAMPLE , UNTIL STOPPED BY LIMIT DETECTOR
3. SET ALL TRANDUCERS CONNECTIONS AND ZERO READOUT.
4. SWITCH CONTROL OPERATIONS OVER TO CONTROL ROOM.
5. START AC DRIVE
6. SET REQUIRED ROCK ROTATION SPEED AND OPERATING TORQUE.
7. OBSERVE DATA CHANNELS FOR APPROPRIATTE READOUTS
8. START TEST CONTROL PROGRAM
   - 8.1. PRE-TRIGGER DATA ACQUISITION
   - 8.2. ROCK SAMPLE MOVES RAPID UP

8.3. ROCK SURFACE INDENTATION OCCURS

8.4. PROGRAM MONITORS ROCK ROTARY POSITION

8.5. AFTER ONE REVOLUTION OF ROCK SEND SIGNAL TO RAPID DOWN UNTIL LIMIT SWITCH STOPS DOWN MOVEMENT.

8.6. AFTER TWO REVOLTION OF ROCK SEND SIGNAL TO STOP DATA ACQUISITION.

8.7. TEST PROGRAM END

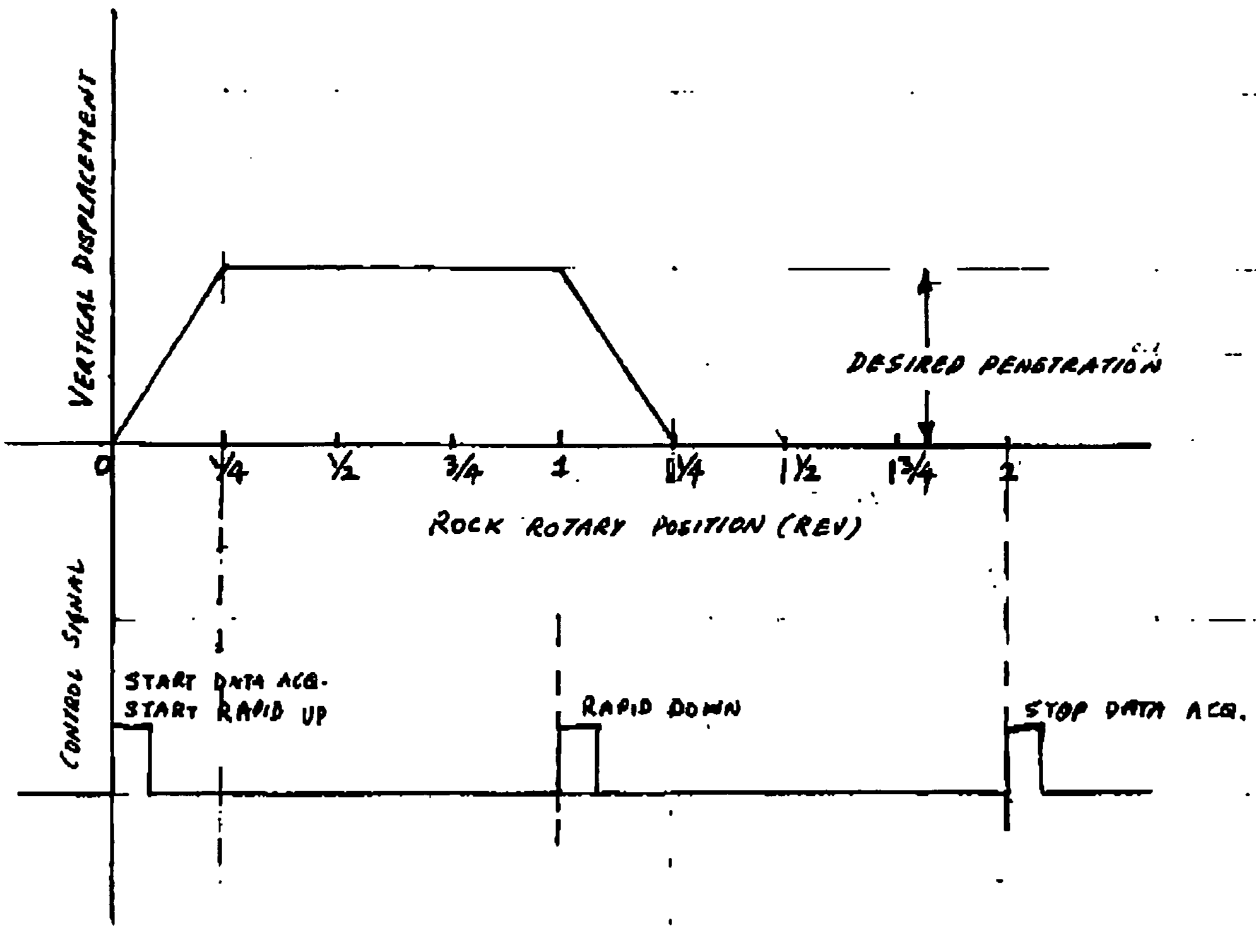
9. STOP AC DRIVE
10. SWITCH CONTROL OPERATIONS TO TEST FRAME
11. OPERATE RELAY TO LOWER ROCK SAMPLE TO BOTTOM END
12. STOP HYDRAULIC PUMP.

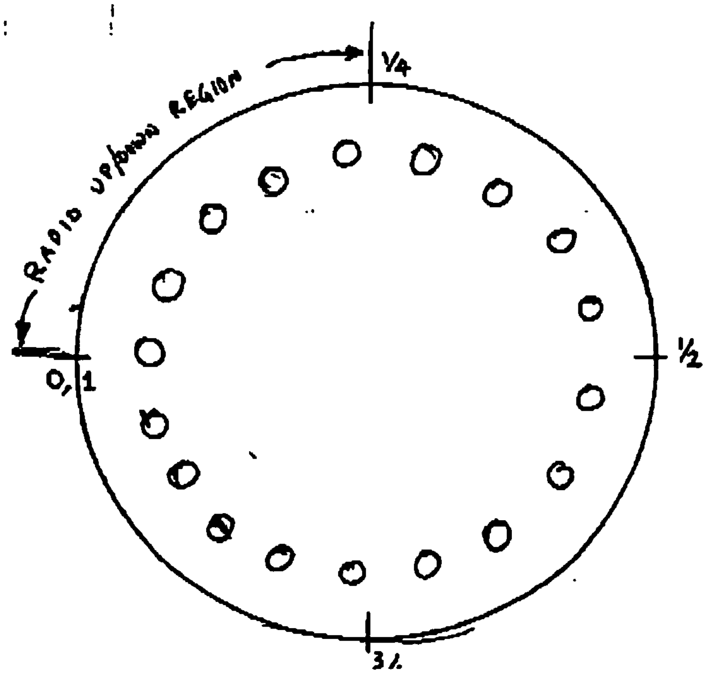
C. POST TEST ANALYSIS

1. PROGRAM TO ANALYSE DATA AND PROVIDE RESULTS

NOTE:

1. IDENTIFIED ANOTHER DATA ACQUISITION SYSTEM WITH SOFTWARE BY NATIONAL INSTRUMENTS WHICH COULD POSSIBLY REPLACE THE PROPOSED IO TECH SYSTEM
2. THIS CONFIGURATION HAS 2 ANALOG OUTPUT TERMINALS IN ADDITION TO THE 8 DIGITAL INPUT CHANNELS.
3. DECISION NOT MADE AS TO WHICH DATA ACQUISITION SYSTEM WILL BE EMPLOYED.
4. REST OF THE SELECTED TRANSDUCERS REMAIN THE SAME.


VERTICAL DISPLACEMENT
DESIRED PENETRATION
0
1/4
1/2
3/4
1
1 1/4
1 1/2
1 3/4
2
ROCK ROTARY POSITION (REV)
CONTROL SIGNAL
START DATA ACQ.
START RAPID UP
RAPID DOWN
STOP DATA ACQ.


RAPID UP/DOWN REGION
1/4
1/2
0,1
3/4

OBJECTIVE OF TEST EQUIPMENT

TO SIMULATE A SINGLE ROLLER CONE INDENTATION AND DRILLING PROCESS UPON A ROCK SURFACE UNDER ATMOSPHERIC CONDITIONS, AND WITH APPROPRIATE INSTRUMENTATION EVALUATE THE FOLLOWING PARAMETERS:

1. TWISTING FORCE (TORQUE) EXERTED ON A SINGLE ROW OF INSERTS WITHIN A CONE.

2. THE AXIAL FORCE EXERTED ON THE INSERT ROW FOR A DEFINED DEPTH OF PENETRATION.

3. DIFFERENT SINGLE ROW INDENTATION PATTERNS.

LOGICAL TESTING SEQUENCE

1. SET UP GEARS SO AS TO OBTAIN DESIRED CONE/BIT SPEED RATIO
2. SET DESIRED SINGLE ROW CONE AND ROCK
3. START HYDRAULIC SYSTEM
4. POWER ON ALL CONTROL SYSTEMS
5. PRESET ALL TRIGGER AND CONTROL LIMITS
6. START AC DRIVE – ROTARY TABLE AND ROLLER CONE ROTATES
7. MANUALLY RAISE ROTARY TABLE TO PRE-DESIGNATED LEVEL
8. SET DATA ACQUISITION SYSTEM
9. EXECUTE TEST
10. POWER OFF AC DRIVE
11. LOWER ROTARY TABLE TO END POSITION
12. STOP HYDRAULIC SYSTEM

VARIABLES WITHIN AN EXPERIMENTAL SET-UP

1. JOURNAL ANGLE : 27°- 42°
2. OFFSET : ± 0.5 INCH.
3. CONE -BIT SPEED RATIO : 1 – 1.7
4. BIT SPEED : 0 – 150RPM
5. RATE OF PENETRATION : CONTINUOUSLY VARIABLE
6. DIFFERENT TYPES OF ROCKS
7. CONES OF BIT SIZE : 6.00" – 12.25"

MEASURING DEVICES

1. AXIAL/TORQUE LOAD CELL:

MEASURE THE AXIAL AND TANGENTIAL FORCEs EXERTED ON THE SINGLE ROW OF INSERTS DURING THE TEST.

2. LVDT

MEASURE AND MONITOR THE PENETRATION RATE.

3. ROTARY ENCODERS/TRANSDUCERS

REQUIRED TO MEASURE THE ROTARY TABLE AND SINGLE CONE SPINDLE SPEEDS.

DATA ACQUISITION CONTROL SYSTEM

1. DATA ACQUISITION SYSTEM
THE FOLLOWING DATA ARE TO ACQUIRED CONTINOUSLY DURIING EACH TEST:

A. AXIAL LOAD
B. TANGENTIAL LOAD
C. RATE OF PENETRATION
D. ROTARY TABLE SPEED
E. CONE ROTARY SPEED

EACH CHANNEL MUST HAVE THE A SAMPLING RATE CAPABILITY OF 30KHz

2. PENTIUM PROCESSOR COMPUTER

3. DIGITAL-ANALOG CONTROL CARDS